Georgia State University

ScholarWorks @ Georgia State University

Psychology Theses

Department of Psychology

5-2-2018

Spoken vocabulary outcomes of toddlers with developmental delay receiving parent-coached augmented language intervention: A phonetic description and analysis

Casy E. Walters

SPOKEN VOCABULARY OUTCOMES OF TODDLERS WITH DEVELOPMENTAL DELAY RECEIVING PARENT-COACHED AUGMENTED LANGUAGE INTERVENTION: A PHONETIC DESCRIPTION AND ANALYSIS

by

CASY WALTERS

Under the Direction of Rose A. Sevcik, PhD and MaryAnn Romski, PhD

ABSTRACT

This study examined the characteristics and predictors of speech sound development of 48 children with developmental delay after participating in parent-coached language interventions. Spoken target vocabulary words were identified for each child and transcribed phonetically. Phonemes were categorized by developmental sound classes and examined for speech sound errors. In general, the majority of children's phonemes and speech-sound errors were age appropriate at the end of intervention and were not significantly different across intervention groups. When baseline predictors were examined, only intervention group and age were significant predictors of the number of spoken target vocabulary words at the end of intervention. Outcomes of this study suggest that clinicians should use AAC with young children with complex communication needs (CCN) to support expressive language development without fear that it will impair articulation skills.

INDEX WORDS: augmentative and alternative communications, speech sound development, developmental disorders

SPOKEN VOCABULARY OUTCOMES OF TODDLERS WITH DEVELOPMENTAL DELAY RECEIVING PARENT-COACHED AUGMENTED LANGUAGE INTERVENTION: A PHONETIC DESCRIPTION AND ANALYSIS

by

CASY WALTERS

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Arts

in the College of Arts and Sciences

Georgia State University

2018

SPOKEN VOCABULARY OUTCOMES OF TODDLERS WITH DEVELOPMENTAL DELAY RECEIVING PARENT-COACHED AUGMENTED LANGUAGE INTERVENTION: A PHONETIC DESCRIPTION AND ANALYSIS

by

CASY WALTERS

Committee CO-Chairs: Rose A. Sevcik and
MaryAnn Romski

Committee: Chris Conway

Electronic Version Approved:

Office of Graduate Studies

College of Arts and Sciences

Georgia State University

May 2018

DEDICATION

To my husband Mark Walters, for his complete backing of my dreams to pursue another degree and patience when listening to me think out loud during this research process. To my future son, thank you for not causing me morning sickness, providing nudges of reassurance, and always being there through the last nine months of this project.

ACKNOWLEDGEMENTS

I would like to express acknowledgement and thanks to my entire committee for their support throughout this research project. Additionally, I would like to especially thank my committee co-chairs, Rose Sevcik and MaryAnn Romski. I could not have completed this project without their patience and encouragement. Lastly, thank you to my friend and colleague, Marika King, for her positive presence.

These data were funded by the National Institutes of Health grant DC-03799 and U.S. Department of Education, Institute of Education Sciences Grant R324A070122 to MaryAnn Romski.

TABLE OF CONTENTS

LIST OF TABLES

1 INTRODUCTION

Purpose of the Study

Within the first six months of life, infants begin to babble the sounds of spoken language. Five years later, typically developing children have gained over 2,000 words in their lexicon (Gammon & Dunn, 1985). Children with developmental delay frequently encounter difficulty with spoken language and speech sound development. These children often participate in early interventions that will support their speech and language development. Early intervention for children who are not yet talking may focus on increasing receptive and expressive language skills that indirectly impact speech sound development. Broadly, the purpose of this study is to characterize and analyze the speech sounds used by toddlers with developmental delays who participated in an augmented and non-augmented parent-coached language intervention research study. A better understanding of how these different types of intervention may impact the development of spoken language at this young age is important to provide early interventionists and parents evidenced based practice to best support their children's development.

1.1.1 Typical Speech Sound Development

Phonemes - the smallest meaningful units of sound – are fundamental to vocal-verbal development in early childhood. In the English language, phonemes are divided into vowels and consonants. Vowels are produced with an unrestricted passage of the airstream through the oral cavity and are typically mastered by three years of age (Bauman-Waengler, 2013; Fudala & Reynolds, 1986; Templin, 1957). Consonants involve more oral-motor effort and are produced by manipulating articulatory muscles that affect the airstream. Consonant phonemes are further categorized by the articulators used (place), how the phoneme is made (manner), and whether or not the vocal folds are occluded (voicing) (Bauman-Waengler, 2013). The production of consonants requires adequate oral-motor development and control, which progresses gradually beginning in infancy and continues through early childhood (Berko-Gleason & Bernstein-Ratner, 2008; Chen & Irwin, 1946; Gammon & Dunn, 1985).

This gradual process towards phonologic development and meaningful speech begins during the pre-linguistic stage of development, or the time before a child's first words. During the pre-linguistic stage, children begin to perceive and produce speech sounds (Flahive & Hodson, 2010). Oller (1980) further categorized the pre-linguistic, developmental period into five stages that describe milestones for children's vocal development. Stage 1: *Phonation* occurs from birth to one month of age and includes the reflexive sounds that are common of newborns (e.g., crying, hiccupping, coughing, and sneezing). In Stage 2: *Coo and Goo*, children use back vowels (e.g., "ah," "aw" "o" "u"), a primitive use of primarily vowel sounds typically seen from two to three months of age. In Stage 3: *Exploration and Expansion*, children use vocal play (e.g., raspberries, yelling, growling) and begin to develop more adult-like vowel sounds as well as some repeated consonant-vowel (CV) syllables between four and six months of age. In Stage 4: *Canonical Babbling*, children from seven to nine months of age produce longer CV syllable strings with more adult-like prosody. The last period Oller described is Stage 5: *Variegated Babbling*. During this phase, children from 10 to 12 months of age continue to use CV combinations but with greater variety in the phonemes used as well as more adult-like intonation. Although the stages described by Oller provide a useful guide for phonemic development, the transition from reflexive sounds to babbling and words is a fluid process and there may be overlap among these stages (Flahive & Hodson, 2010; Gammon & Dunn, 1985).

Like Oller, Piaget (1964) also used developmental stages to characterize cognitive development. Although Piaget's model included four distinct developmental stages, the first stage (the sensorimotor stage) is most relevant to vocal-verbal development. Within the sensorimotor stage of development (0-2 years of age), he described six more discrete stages of development that outline the process of children learning to imitate. According to Piaget, infants begin by using imitation reflexively (e.g., crying when other children are crying) and mature to more systematic use of vocal imitation for the purposes of communication (e.g., repeating words and phrases). Vocal imitation is thought to help children practice using the phonemes they hear in their environment and is an indicator of early language learning (Kuhl & Meltzoff, 1996). Although it is still unclear how environmental factors (e.g., parental response) may influence the development of vocal imitation, vocal imitation is a signal that children are preparing to use spontaneous spoken language to communicate (Bandura & Barab, 1971; Diehl & Paul, 2012; Kuhl & Meltzoff, 1996; Rees, 1975).

As children are exploring their spoken abilities by babbling, imitating, and saying their first words, many children exhibit protowords, or phonetically consistent forms (PCF) of words. PCFs are consistent vocalizations that do not sound like adult words but are used to express a consistent meaning (e.g., “ab” for ball) (Peña-Brooks & Hedge, 2000). Some children use these PCFs even after they begin to use connected speech but these instances typically decrease over time as a child’s expressive vocabulary and articulation skills increase. By age eight, the majority of typically developing children are accurately producing all phonemes found in the English language in adult like form during conversation (Gammon & Dunn, 1985; Sander, 1972; Smit, Hand, Freilinger, & Bird, 1990; Templin, 1957).

Developmental norms provide a general idea for when individual phonemes are typically mastered in 90 percent of children (Templin & Steer, 1939). These norms help inform parents, speech-language pathologists (SLPs), and pediatricians whether a child’s phonemic development is following a developmentally appropriate track. Failure of a child to meet developmental norms may prompt parents, teachers, and pediatricians to seek out or recommend speech therapy if a child cannot accurately generate developmentally appropriate phonemes in isolation or during co-articulation. Many studies list phonemes hierarchically, cataloging the order in which phonemes are typically acquired (Arlt & Goodban, 1976; Poole, 1934; Prather, 1975; Smit et al., 1990; Templin, 1957; Wellman, Case, Menegert, & Bradbury, 1931). This structure may not illustrate a true picture of phoneme development because there are multiple sounds that may share similar defining features (e.g., place or manner of production) that arise in a child's phonemic repertoire almost simultaneously. To create a developmental pattern that captured a holistic perspective of development, Shriberg (1993) created norms that did not order the phonemes by age of acquisition; rather he grouped them in "developmental sound classes" that are categorized based on sounds that are typically acquired together: Early-8 /m, b, j, n, w, d, p, h/ Middle-8 /t, ŋ, k, g, f, v, tʃ, ʤ/, and Late-8 /ʃ, ð, s, z, θ, l, r/.

In addition to examining the acquisition and development of individual phonemes, it is also necessary to observe the broad patterns of phonological acquisition (e.g., consonant clusters). Ingram (1976) first described the development of the speech sound system in terms of patterns of errors typically present in children's speech, or phonological processes (e.g., final consonant deletion, fronting, cluster reduction). Grunwell (1981) observed the speech of typically developing children to outline when these phonological processes emerge in speech development and when they are suppressed. He noted that final consonant deletion, cluster reduction, stopping, fronting, gliding, and devoicing are commonly occurring phonological processes generally suppressed around age three. A few phonological processes may persist until ages four and five (e.g., stopping: d/ð, gliding: w/r). Shriberg (1993) also suggested that children with delayed speech and language skills (i.e., “late-talkers”) exhibit the same phonological processes as typically developing children but at later times. Although their speech is delayed, they do not use atypical or idiosyncratic phonological processes when they begin to develop speech.

1.1.2 Measuring Speech Sound Development

As phonemes are developing, it is important for professionals working with children to have measures that can describe and track a child’s accuracy producing sounds. There are many standardized measures that help to characterize accuracy of phoneme production such as the Goldman-Fristoe Test of Articulation, Second Edition, (GFTA; Goldman & Fristoe, 2000), Arizona Articulation Proficiency Scale, Third Edition, (Arizona-3; Fudala, 2000), and Clinical Assessment of Articulation and Phonology, Second Edition, (CAAP-2; Secord & Donohue, 2014). However, most of these measures are only appropriate and normed for children beginning at two years of age and older due to the expressive language requirements during the assessment. For similar reasons, these assessments are not always appropriate for children with developmental disabilities. Shriberg and Kwiatkowski (1982) developed the percent of consonants correct (PCC) measure to assess an individual’s accuracy using consonants when compared to the gloss. In this method of assessment, a child or individual’s articulation skills can be evaluated without answering questions. The PCC provides a percentage that is characteristic of the child’s ability to produce consonants in an adult-like form. This measure was normed using conversational speech samples from participants ranging from age four to 54. Based on these norms, severity ratings are available to qualitatively label the accuracy of individuals in this age range compared to others the same age. Although this measure is normed with preschoolers through adulthood, it is a tool to describe an individual’s accuracy producing consonants in a given language sample. It also was specifically designed to better assess children and adults with more than typical distortions of individual phonemes (Shriberg, 1993). This tool provides a more subtle way to track progress and generalization of speech sounds to conversation. Subsequent revisions to the PCC measure, percent of consonants correct-revised (PCC-R; Shriberg & Austin, 1997), have given children more developmental leeway by not calculating distortions (e.g., dentalized /s/ or derhoticized /r/) as errors. Instead, the PCC-R only uses substitutions, omissions, and/or epenthesis to categorize erred consonants.

1.1.3 Speech Sound Errors in Children with Developmental Disabilities

Children with developmental disabilities often have a range of difficulties acquiring expressive language skills and also may demonstrate delayed or atypical speech sound development. Bauman-Waengler (2013) summarized common speech characteristics of children with intellectual disabilities as having increased frequency and persistence of speech sound errors and deletion of consonants. Although it is difficult to have any more specificity due to the extreme variance among children with intellectual disabilities, there has been more focused research within specific disabilities that attempts to describe speech developmental norms for different populations (Kent & Vorperian, 2013; Shriberg, 1993; Smith & Stoel-Gammon, 1983). However, it should be noted that even within the diagnoses of cerebral palsy, Down syndrome, and delayed speech, the cognitive, language, and speech abilities of individual children still vary greatly.

Many young children with cerebral palsy (CP) commonly exhibit distortions of vowels and a decreased percent of unintelligible words due to oral-motor impairment (Hustad, Allison, McFadd, & Riehle, 2014). Specific articulation difficulties may be different depending on the type of motor-involvement: spasticity, dyskinesia, or ataxia. Children with the spastic type of CP may have difficulties producing fricatives and affricates, as well as a slowed rate of speech. Due to overall large jaw movements during speech, children with the dyskinetic type of CP often have difficulties articulating phonemes that require a stable jaw. The ataxic type of CP may affect a child's ability to produce precise phonemes that lead to sound distortions, substitutions, and omissions (Bauman-Waengler, 2013; Ingram, 1977). In general, these specific groupings of speech characteristics will typically fall under the broad term dysarthrias.

Children diagnosed with Down Syndrome (DS) often exhibit a delayed speech profile during the first few years of life and persistent difficulties with phonological processes (Kent & Vorperian, 2013; Kumin, Councill, & Goodman, 1994; Smith & Stoel-Gammon, 1983). These difficulties may be due to one or a combination of the following factors: common hearing loss, differences in cranial-facial anatomy, cognitive abilities, and language environment (Stoel-Gammon, 2001). In 1976, Dodd examined the phonological systems of 30 mental-age matched children (mean mental-age: 3;6) in three groups: typically developing, severe learning difficulties, and DS. The authors found that children with DS exhibited more idiosyncratic speech errors and phonological processes than the other two groups. Although children with DS demonstrated on-going difficulties with developmentally appropriate phonological processes, they also had more success when imitating spoken words compared to spontaneous word production. Kumin et al. (1994) cautioned that when examining the speech sound development in children with DS, using typical developmental patterns may not be applicable due to overall differences in speech sound mechanisms (e.g., craniofacial abnormalities) and cognition.

Similar to children with DS, children who are "late-talkers" also tend to use appropriate, but delayed phonological processes and have highly variable speech abilities and outcomes (Paul & Norbury, 2012; Preston, Irwin, & Turcios, 2015; Shriberg, 1993). These children also may be described as having an expressive language delay/disorder. Some children who are late-talkers may achieve accurate articulation by age eight along with typically developing children; others continue to struggle with articulation errors indefinitely (Preston et al., 2015). In a comparison of late talking and typically developing children, Shriberg (1993) found that overall children with expressive language delays did not exhibit phonological processes or articulation distortions any more frequently that typically developing children, except in their increased use of final consonant deletion (FCD).

Children with developmental disorders and language delays across diagnoses commonly have a higher use of articulation errors and phonological processes, which persist beyond the typical extinction period (Kent & Vorperian, 2013; Shriberg, 1993; Sommers, Reinhart, & Sistrunk, 1988; Van Bysterveldt, 2009). Some children, after speech-language therapy and/or maturation of their oral-motor systems, will eventually attain typical speech, but others will continue to struggle with the accurate production of speech sounds throughout their lifetime. To more fully understand the difficulties some children face, it is important to consider what factors contribute to spoken-language development. It is possible that pre-linguistic markers such as the presence of vocal imitation could help predict their speech outcomes of children with developmental delays. Discussion of the role that imitation plays in first language acquisition for both typical and children with language delay has occurred for decades (McNeil, 1970; Rees, 1975; Slobin & Welsh, 1967). In 1975, Rees posited that the relationship between imitation and language acquisition was unclear, and hypothesized that perhaps imitation is necessary for further language development. More recent research has confirmed the causal relationship between vocal imitation and spoken language acquisition in typically developing children (Fitch, 2005; Kuhl & Meltzoff, 1996). In children with developmental disorders, however, vocal imitation is often absent or delayed.

Warren, Yoder, Gazdag, Kim, and Jones (1993) examined factors that might facilitate improved communication skills of two-year old children with developmental delays enrolled in a university preschool early intervention program. The authors hypothesized that children without vocal imitation skills could be taught this skill during intervention to encourage further spoken utterances. Using milieu-teaching strategies, interventionists encouraged vocal imitation by recasting a child's vocalizations and making them more functional pairing them with an action or object (e.g., recasting: Child: "ball" Interventionist: "throw ball!"). Warren and colleagues found that intervention using these strategies increased the child's ability to request, comment, and imitate vocally. This finding indicates that even if a child has disordered or delayed language development, pre-linguistic skills, such as imitation, can be taught during intervention to facilitate further language growth. If children with language delays are beginning to imitate vocalizations as a result of goal-oriented intervention or a delayed developmental trajectory, then it would follow that these children are developmentally ready and equipped with at least one of the tools needed to begin using spontaneous spoken language.

1.1.4 Augmentative and Alternative Communication and Speech Outcomes

Some children may not begin developing vocal-verbal language due to impairments in expressive language, physical oral-motor, and/or cognitive skills. Children who have great difficulty with spoken communication may learn to use augmentative and alternative communication (AAC) as an alternative language modality. AAC allows individuals with impaired expressive language skills to participate in communication interactions by limiting motor demands through the use of symbols for expression (Blischak, Lombardino, & Dyson, 2003; Romski & Sevcik, 1996; Smith & Grove, 2003). There have been many studies that report language growth as an outcome of AAC intervention (Barton, Sevcik, & Romski, 2006; Branson & Demchak, 2009; Romski et al., 2010). There is also increasing support that AAC intervention may result in increased vocal and speech development (Bauman-Leech & Cress, 2011; Millar, Light, & Schlosser, 2006; Romski & Sevcik, 1996). Romski, Sevcik, and Pate (1988) reported positive speech outcomes for a young woman receiving AAC intervention using a computerized communication system. Diagnosed with mental retardation and dysarthria, she was noted to improve her overall word approximation skills, acquire two conventional spoken words, as well as increase from single syllable to bi-syllabic approximations. In a systematic literature review, Millar et al. (2006) identified 23 AAC intervention studies between 1975 and 2003 that reported speech outcomes before, during, and after intervention. Speech outcomes were identified and operationalized based on the methods of the included study (e.g., intelligible words produced; oral production of short, multiword phrases), which made it difficult to compare spoken development across studies. These 23 studies included a total of 17 participants and only one study which used AAC with speech output in its intervention. In this study, Blischak (1999) examined the effect of rhyme intervention using graphic symbols alone and graphic symbols coupled with synthetic speech (i.e., a speech generating device, SGD). She found that children who received intervention with a synthetic SGD on average demonstrated a greater percentage of spoken language responses from pre to post assessment than children who received the same intervention without synthetic speech.

1.1.5 Speech Generating Devices

SGDs are a type of AAC that couple symbols with digitized, or synthesized speech. An SGD allows an individual to communicate words or phrases auditorily through picture-symbols or text with voice output. An SGD provides an individual with an opportunity to communicate with spoken words even if they cannot vocally produce words or if their speech is difficult for others to understand. From a social-conversational perspective, SGDs give the user a chance to switch from a more passive role in communication to becoming an "active participant," literally gaining a voice. Furthermore, SGDs reduce physical demands and pressures to speak when compared to using gestures, sign language, or unaided AAC methods (Blischak et al., 2003; Romski & Sevcik, 1996). When AAC in the form of an SGD is used in early intervention, it provides not only a means of communication but also a consistent mode of production via digitized or synthetic speech. This provides an acoustically consistent form of the target vocabulary, which may allow for the child to pay more attention to target vocabulary and provide opportunity for vocal imitation of the SGD (Blischak et al., 2003; Romski & Sevcik, 1996; Schlosser & Blischak, 2001). Including Blischak's (1999) study, there have been several published studies that note positive spoken language effects following an intervention facilitated by SGDs for children on the autism spectrum (e.g., Olive et al., 2007; Parsons & LaSorte, 1993; Schlosser et al., 2007) and with severe developmental delay (e.g., Romski et al., 2010).

Romski et al. (2010) aimed to compare the effects of early parent-coached intervention using SGDs on symbolic language development of toddlers with severe developmental delay. In the study, children were randomly assigned to one of three different intervention groups: augmented communication input (ACI), augmented communication output (ACO), and spoken communication input (SCI). The ACI group received AAC intervention with parent and interventionist models and input using the AAC system. The ACO group also received AAC intervention but with hand-over-hand assistance for child AAC productions. The spoken communication group received language intervention without AAC. At the end of the study, the vocabulary sizes of participants in the augmented groups (ACI, ACO) were significantly larger than those of the SCI group, with the ACO group developing the largest vocabulary. Vocabulary size was operationalized as a participant using a target word in any available form (i.e., augmented, spoken, or combined). In addition, even when spoken output was examined in isolation, the number of spoken target vocabulary words was greater for the augmented groups when compared to the SCI group. The ACI and ACO groups received no prompts to use spoken language yet children in these groups were 2.9 and 4.8 times more likely to use spoken language compared to the spoken communication group.

Despite research evidence demonstrating the benefits of AAC for developing language and speech skills, hesitation persists for parents and professionals in using this method with the fear that spoken-verbal communication will be hindered (Romski & Sevcik, 2005). There are no known studies to date that specifically investigate the effects of AAC on articulation development in addition to spoken-vocabulary outcomes in very young children with developmental disorders. This broader examination of the effects of AAC intervention may provide parents, professionals, and researchers a more robust picture of the benefits of this type of intervention (Leech & Cress, 2011; Millar et al., 2006; Schlosser & Wendt, 2008).

This study will consider the effects that parent implemented intervention utilizing SGDs has on the spoken language of toddlers with developmental disabilities. It will explore spoken outcomes of the intervention by characterizing the phonetic make-up of the participants' spoken target vocabulary in an effort to understand if this type of intervention received affected vocal-verbal speech production. Further understanding of the use of SGDs and their effects on spoken language might ease fears and reservations that parents and clinicians have about using this type of intervention with very young children with developmental disabilities.

Research Aims

The current study characterizes the phonetic make-up of the children's spoken target vocabulary words to determine if they follow typical developmental patterns. Based on previous research that describes children with language delays as also having speech delays, including typical and atypical speech sound errors, it is expected that the children in this study will present with speech delays characterized by typical and atypical speech sound patterns.

The second aim is to identify if augmented interventions using SGDs have an effect on the phonemic accuracy of spoken target vocabulary compared to a non-augmented intervention. It is expected that the increased opportunity for phonetically consistent presentations of target vocabulary on SGDs will increase the phonemic accuracy of spoken target vocabulary words for children participating in AAC interventions compared to children in the SCI group. It also is hypothesized that children in a hybrid intervention group that combines both augmented input and augmented output techniques (ACIO), will have more spoken words as well as increased accuracy due to the combined effects of input from symbols in the environment and on the SGD and direct prompts to use the SGD for communication.

Aim three of this study is to examine which factors influence spoken target vocabulary outcomes including vocal imitation and receptive language skills at baseline. Yoder and Layton (1988) showed that when children used vocal imitation at baseline, language intervention using sign language (i.e., an unaided form of AAC) yielded the best spoken language outcomes. Thus, we hypothesized that in the current study, children who demonstrate greater vocal imitation will demonstrate increased spoken language outcomes. Albert, Romski, and Sevcik (2017) suggested that receptive language moderated target language outcomes of Romski and colleagues' (2010; In preparation) AAC intervention studies. Therefore, we hypothesize that for the current study, receptive language at baseline will explain a significant portion of the variance in PCC measures of spoken outcomes.

2 METHOD

The current study used data from two larger early language intervention studies (Romski et al., 2010, Romski et al., in preparation). Sixty-two and 51 children completed the intervention in the first and second studies respectively. All 113 children were considered for the current study.

Participants

Children were recruited to the original studies based on the following criteria: a) 24 to 36 months of age at the beginning of recruitment; b) significant developmental delay as defined by Mullen Scales of Early Learning (MSEL; Mullen, 1995); c) an expressive vocabulary of less than 10 intelligible spoken words; d) significant expressive language delay (i.e., less than 12 months on the MSEL); e) indication of intentional communication (e.g., intentional gestures, joint attention, vocalizations); f) upper extremity motor control to access symbols on the speech generating device (SGD); and g) primary diagnosis other than delayed speech and language skills, hearing/vision impairment, or autism.

The current study focused on the 48 children (12 females and 34 males) from the two samples (42%) who produced at least one spoken target vocabulary word at session 18 and/or session 24. The 48 children were distributed across the four intervention conditions: ACO (*n* = 16)*,* ACI (*n* = 6), SCI (*n* = 6)*,* and ACIO (*n* = 10).[1] The mean chronological age for these children was 31.09 months, and included children from African American (*n* = 18), Asian (*n* = 4), multi-racial (*n* = 1), and Caucasian (*n* = 23) backgrounds. The children were diagnosed with variety of disorders including: apraxia of speech, cerebral palsy, Down syndrome, developmental disability, mitochondrial disorder, pervasive developmental disorder, speech delay, seizure disorder, and unknown etiology. At baseline and post-intervention, each child received a battery

[1] The AC-O intervention was repeated in Romski et al., (in preparation) study based on the findings from Romski et

of assessments that included: the MSEL (Mullen, 1995); Vineland Adaptive Behavior Scales, Second Edition (Vineland-2; Sparrow, Cicchetti, & Balla, 2005); MacArthur-Bates Communicative Development Inventories: Words and Gestures (MCDI; Fenson, Bates, & Dale, et al., 1996); and the Sequenced Inventory of Communication Development, Revised (SICD-R; Hedrick, Prather, & Tobin, 1984).

Intervention

As described in Romski et al., (2010) and Romski et al., (in preparation), participants were randomly assigned to one of four intervention groups (see Table 1): spoken input (SCI), augmented communication output (ACO), augmented communication input (ACI), and a hybrid augmented communication input and output (ACIO). Intervention usually occurred twice per week for 24 sessions, 18 sessions within a laboratory environment and 6 at the child's home. Interventionists were trained on how to deliver each type of intervention and had obtained at least a bachelor's degree before joining the study. For each type of intervention, four key components (target vocabulary, parent coaching, mode, and strategies) were targeted during three 10-minute routines (play, book, and snack). Specific strategies for the interventionist and/or parents included prompting techniques related to the intervention group (see Table 1). The SCI group served as a contrast to the augmented groups, and parents were coached to visually and verbally prompt children by encouraging them to look at the mouth of the interventionist/parent and cueing them to respond using their mouth (e.g., "*tell me using your mouth"*). The children in the ACO, ACI, and ACIO did not receive any prompts to use vocal-verbal communication. Children in the ACI group were not prompted to communicate on the device, but were naturally reinforced (e.g., received desired object) if they used the device to communicate. The ACO and ACIO groups received visual, verbal, and physical (i.e., hand-over-hand) prompts to encourage the child to communicate using the SGD. Interventionists and parents would cue the children in these groups by tapping or pointing to the SGD and saying, "*tell me here.*"

In addition to specific strategies related to the assigned intervention group, all parents were taught general strategies to facilitate language (e.g., limit utterance length, provide choices) by a speech-language pathologist (SLP) while they observed through a one-way mirror during the first 8 sessions. Parents were able to practice using general and specific strategies beginning in session 9 during the 10-minute snack routine and were provided with feedback from the interventionist. By session 16, the parent led all three parts of the intervention, and continued to lead for the remaining sessions.

Intervention both in the laboratory and at home provided a naturalistic environment. Parents and interventionists followed the child's lead during three routines and encouraged them to communicate for a variety of purposes (e.g., to request, to comment). In the ACI and ACIO groups, symbols also were used to label the environment as another level of input for the child.

Target Vocabulary

Each child was given a selection of target vocabulary words, chosen by the parent and the speech-language pathologist, to use throughout the intervention. The child did not comprehend or produce the target vocabulary words prior to intervention, were motivating to the child based on parent report, and were easily generalizable to the child's home setting. Developmental appropriateness of phonemes in target words was not considered in target word selection. Each child had target vocabulary unique for each routine (i.e., play, book, and snack) and words that would generalize across routines (e.g., *more, all done, what's this*). Vocabulary words in the SCI group were presented orally, without picture symbols. The ACI, ACO, and ACIO groups all used symbols from Picture Communication Symbols (Mayer-Johnson, 1981) to represent target vocabulary graphically on SGDs. Additional vocabulary words were added when the child was using a majority of the vocabulary available. The total number of target vocabulary words introduced across all sessions ranged from 10 to 64 target words.

Table 1
Components of four interventions[2]

Component	SCI (Study 1)	ACI (Study 1)	ACO (Study 1 & 2)	ACIO (Study 2)
Mode	I/P and child use speech to communicate	I/P uses SGD to provide communication input to child	Child uses SGD to communicate	I/P uses SGD to provide communication input to child
Target vocabulary	Individualized vocabulary of spoken words	Individualized vocabulary of visual-graphic symbols + words	Individualized vocabulary of visual-graphic symbols + words	Individualized vocabulary of visual-graphic symbols + words
Strategies	I/P encourages and prompts the child to produce spoken words	I/P provides vocabulary models to child using the device; symbols are positioned in the environment to mark referents	I/P encourages and prompts the child to produce communication using the device	I/P provides vocabulary models to child by using the device; symbols are positioned in the environment to mark referents; I/P encourages and prompts the child to produce communication using the device
Parent coaching	I provides resource and coaching for P	I provides resource and coaching for P	I provides resource and coaching for P	I provides resource and coaching for P

Note: I=interventionist; P=parent

[2] From Romski, M. A., Sevcik, R. A., Cheslock, M., & Barton-Hulsey, A. (2016). The system for augmenting language: AAC and emerging language intervention. In R. McCauley, M. Fey, & R. Gillam (Eds.) Treatment of language disorders in children: Conventional and controversial interventions, 2nd ed. (pp. 155-186). Baltimore, MD: Paul H. Brookes Publishing.

Videotape records were made for all 24 sessions. The baseline, 18th, and 24th sessions were transcribed using Systematic Analysis Language Transcripts (SALT, Miller & Chapman, 1985). This study analyzed the characteristics of the spoken target vocabulary at the end of intervention in the laboratory setting (session 18) and the culmination of the intervention program after six additional home visits (session 24).

Data Analysis

Using the extant database from Romski et al. (2010) and Romski et al., (In preparation), spoken target words were located in the SALT transcripts and in the accompanying videotape. Spoken words were defined as a combination of sounds that were consistently used by the child or parent and interpreted by the listener as a word (Romski et al., 2010), which included spoken words that also were combined with augmented forms (e.g., SGD). Unintelligible vocalizations were not coded, but transcribed as "XX" in the original study and therefore were not transcribed in this study. Spoken target-vocabulary transcribed for each child were analyzed initially for the total number of different spoken words to examine the overall diversity in acquired spoken-vocabulary across intervention groups.

The phonetic make-up of each participant's spoken target-vocabulary was analyzed by transcribing spoken target vocabulary words using the International Phonetic Alphabet (IPA). Consonant and vowel sounds were identified as correct or incorrect and categorized based on the following articulation and phonological error categories: substitution, final consonant deletion, deletion, cluster reduction, or other. From the phonetic transcription, percent of consonants correct, revised (PCC; Shriberg & Kwiatkowski, 1982) was calculated ($\frac{(\#consonants\ correct}{\#consonants\ targeted}$ x 100) for each child's spoken target vocabulary. Phonemes from spoken target vocabulary words were categorized as Early, Middle, or Late-8 sounds and totaled for each participant.

To predict whether the child's ability to imitate speech sounds predicted their use of spoken, target vocabulary, specific and relevant items were considered from the following assessments administered at baseline (see Table 2): Vineland-2 (Sparrow et al., 2005); MCDI (Fensen et al., 1993); and SICD-R (Hedrick et al., 1984). The ability to imitate speech sounds and spoken language were operationally defined by an affirmative score on two out of the three items on the assessment measures. To predict if receptive language skills at baseline predicted spoken language outcomes, we used the receptive language age equivalent from the MSEL (Mullen, 1995).

Table 2
Item description for measures used to operationalize imitation

	MCDI[a]	SICD-R[a]	Vineland-II[b]
Imitating words	+	-	+
Imitatingsounds/syllables	-	+	-

Note: [a]=measured by parent report; [b]= measured by examiner, unless not demonstrated then measured by parent report.

To investigate if intervention group had an effect on the accuracy of consonants in different developmental classes, we used a four by four multivariate analysis of variance (MANOVA) design, with each developmental class (i.e., early, middle, and late eight) as well as an overall PCC measure as dependent variables. The independent variable, intervention assignment, also had four levels: ACO, ACI, ACIO, SCI. We used the F-test to determine if there was a significant omnibus effect and post-hoc analyses to examine the nature of that effect. The assumptions of normality and homogeneity of variance were assessed using the Kolmogorov Smirnov and Levene's tests.

To examine the effects of baseline imitation, receptive language, and diagnosis on the accuracy of spoken target words, we conducted a multiple linear regression. We used a hierarchical method to enter predictors into the model in different steps. Albert, Romski, and Sevcik (2017) suggested that receptive language moderated overall expressive language outcomes in this intervention. Therefore we entered receptive language at baseline in Step 1, with imitation and diagnosis in Step 2 to determine if these variables contributed any unique variance above and beyond receptive language. Predictors were evaluated by their unique contribution to the prediction of percent of consonants correct. The F-test was used to determine the fit of both models. R-squared was reported and used to determine the amount of variance in the dependent variable that could be accounted for by these predictors. T-tests were used to determine the significance of each predictor. The assumptions of linearity, homoscedasticity, and multicollinearity were assessed.

3 RESULTS

The four groups were compared based on participant characteristic measures including age, ethnicity, and diagnosis. One-way analysis of variance (ANOVA) revealed non-significant differences for sex, ($F(3,42) = 1.09$, $p = .37$), ethnicity, ($F(3,42) = .045$, $p = .99$) and diagnosis, ($F(3,39) = .15$, $p = .93$); a significant difference was noted for age, ($F(3,41) = 3.66$, $p = .02$). Contrasts comparing each group to the other three suggested that the ACI group was significantly younger and the ACIO group was significantly older compared to the other intervention groups (ages by group listed in Table 3 and 4). Additionally, the correlation between age and the number of different target vocabulary words was significant for session 18, $r = .51$, and session 24, $r = .38$ (see scatterplot in Appendix A). Therefore, age was considered as a covariate in our analyses.

Target words were chosen based on content not phonemes. Therefore, due to differences in the phonemes represented in each vocabulary word across participants, some children did not have the opportunity to use sounds within a specific category. This resulted in missing data for these participants and varying sample sizes across different measures. To simplify this difficulty, we imputed means from the appropriate intervention group for missing data as recommended by Widaman (2006). These imputations did not result in any statistical differences when *t*-tests were compared across groups (see Appendix A).

Aim 1: Characterizing phonetic make-up

To characterize the phonetic make-up of the children's spoken target vocabulary words, the four groups were compared on measures of phoneme accuracy and error pattern use. This included percent of phonemes correct (PPC), PCC, and five types of error patterns (substitution, omission, cluster reduction, final consonant deletion, and vowel distortion). Descriptive statistics for phoneme level data in session 18 and 24 are presented in Tables 3 and 4. On average, 81.5 percent of the spoken target vocabulary phonemes were accurately produced. Across intervention groups, the majority of errors (75.5%) were age appropriate. Additionally, the number of erred phonemes in spoken target words were highly correlated with the number of different words produced (see correlation tables in Appendix B). In Sessions 18 and 24, the SCI group used the least number of words and phonemes, but produced the most accurate forms of words. Conversely, the ACIO group used the most words and exhibited more errors in their productions.

Table 3
Session 18 Description of errors in production by phonemes

	ACO(*n*=16)	ACI(*n*=6)	SCI(*n*=6)	ACIO(*n*=10)
Group Descriptors *M(SD)*				
Age at Baseline	30.71(5.31)	27.56(4.00)	30.44(3.89)	35.50(5.80)
Number of different spoken target words	6.08(4.92)	3.20(3.49)	1.11(.78)	8.60(4.17)
Phoneme Descriptions *M(SD)*				
PPC	.84(.27)	.86(.24)	.93(.17)	.77(.30)
PCC (Early-8)	0.85(.28)	.73(.41)	1(0)	.90(.16)
PCC (Middle-8)	.95(.17)	.86(.22)	.92(.20)	.90(.13)
PCC (Late-8)	.82(.23)	.90(.14)	.92(.20)	.62(.31)
PCC (Total-8)	.90(.14)	.82(.28)	.90(.24)	.80(.18)
Categorization of Errors *M(SD)*				
Final Consonant Deletion	.50(.89)	.50(.53)	.17(.41)	1.20(1.32)
Substitution	.63(1.56)	.17(.41)	.17(.41)	1.40(1.17)
Deletion	.19(.40)	.17(.41)	0	.70(.82)
Cluster reduction	.38(.72)	.17(.41)	.17(.41)	1.30(.68)
Vocalic /r/ errors	.38(.72)	.17(.41)	0	.70(.48)
Vowel errors	.06(.25)	.20(.42)	0	.13(.34)
Other	.13(.34)	0	0	0

Note: Errors were totaled by number of effected phonemes. A score of 0 means there were no errors recorded. If participants did not use sounds from a specific sound class, their average use across other productions was imputed to compensate for missing data.

Table 4
Session 24 Description of errors in production

	ACO(*n*=14)	ACI(*n*=7)	SCI(*n*=4)	ACIO(*n*=13)
Group Descriptors *M(SD)*				
Age at Baseline	30.71(5.31)	27.56(4.00)	30.44(3.89)	35.50(5.80)
Number of different spoken target words	6.08(4.92)	3.20(3.49)	1.44(1.51)	8.60(4.17)
Phoneme Descriptions *M(SD)*				
PPC	.86(.09)	.70(.35)	.98(.04)	.76(.18)
PCC (Early-8)	0.85(.28)	.73(.41)	1(0)	.90(.16)
PCC (Middle-8)	.95(.17)	.86(.22)	.95(.11)	.90(.13)
PCC (Late-8)	.82(.23)	.90(.14)	.60(.42)	.62(.31)
PCC (Total-8)	.90(.14)	.82(.28)	.82(.21)	.80(.18)
Categorization of Errors *M(SD)*				
Final Consonant Deletion	.57(.76)	.33(.52)	0	.62(.77)
Substitution	.86(1.41)	.50(.84)	0	1.31(1.45)
Deletion	.29(.61)	0	.20(.45)	.54(.78)
Cluster reduction	1.07(1.14)	.50(.55)	0	1.31(1.32)
Vocalic /r/ errors	.36(.63)	.50(1.23)	0	.85(1.14)
Vowel errors	.14(.54)	0	0	.38(.97)
Other	.43(1.16)	0	0	0

Note: Errors were totaled by number of effected phonemes. A score of 0 means there were no errors recorded. If participants did not use sounds from a specific sound class, their average use across other productions was imputed to compensate for missing data.

Aim 2: Phoneme accuracy between groups

Prior to proceeding with linear statistics, we tested the assumptions of linearity, homoscedasticity, and normality. We examined skew and kurtosis data and residual plots for each independent variable compared to the residuals. These comparisons revealed no concern for skew or kurtosis, but we did observe limited funneling in the residual plot. Despite this observation, we did not determine that this irregularity was significant enough to warrant transforming the data and losing the inherent variability in our comparisons. A correlation matrix of the independent variables allowed us to examine possible colliniarity issues. Two potentially relevant, significant correlations emerged at baseline between receptive language and unintelligible vocalizations as well as receptive language and vocal imitation (r = .33, p = .02 and r = .29, p = .04 respectively). These correlations were modest, and did not raise concerns in the variance inflation factors (VIF) or tolerance statistics.

We used a one-way ANOVA to determine if there were group differences in their use of speech sound error patterns at sessions 18 and 24. Results revealed no significant differences between groups at session 18. At session 24, only cluster reduction was significantly different across groups, F(3,34) = 6.61, p =.001. Post-hoc analysis using Tukey's honest significant difference (HSD) revealed significant differences between ACO and ACIO (p =.005), ACI and ACIO (p =.007), and SCI and ACIO (p =.007) such that the ACIO group exhibited more cluster reductions compared to the other groups. To better understand this difference, the number of clusters available in target vocabulary words were examined and there were no significant differences between groups, $F(3,44)$ = 1.09, p = .36.

Additionally, we conducted a 4x4 MANOVA to investigate if augmented interventions using SGDs had an effect on the accuracy of phonemes in different developmental classes compared to non-augmented intervention. At session 18, there was no significant effect of intervention group on Early-8, Middle-8, Late-8, and Total PCC, V(12, 99)=.54, p=.057, η^2=.18. At session 24, there was a significant effect of intervention group on the Early-8, Middle-8, Late-8, and Total PCC at session 24, V(12, 99)=.66, p=.01, η^2=.22. Separate univariate ANOVAs on the outcome variables revealed non-significant treatment effects of group for Early 8 PCC F(3,34) =.859, p =.47, Late 8 PCC F(3,34) =.58, p =.64, and Total PCC, F(3,34) = 2.54,p =.07. The univariate ANOVA for Middle 8 PCC at session 24 revealed significant differences between groups, F(3,34) = 3.49, p = .03, η^2 = .24. Post-hoc, simple contrasts revealed that the ACIO group was significantly more accurate than the ACI group in Middle-8 sounds. There were no significant differences between the ACO and SCI group when compared to the ACIO group.

When age was added as a covariate at session 18, there was no significant effect of intervention group on any of the developmental sound classes, $V(12, 90)$=.1.38, p=.19, η^2=.15. At session 24, the significant effect of intervention group remained, $V(12, 87)$=1.95, p=.04, η^2=.21. Separate univariate ANOVAs on the outcome variables revealed non-significant treatment effects of group for Early 8 PCC $F(3,34)$ =.55, p =.65, Late 8 PCC $F(3,34)$ =.63, p =.60, and Total PCC, $F(3,34) = 2.90$, p =.05. The univariate ANOVA for Middle 8 PCC at session 24 revealed significant differences between groups, $F(3,34) = 3.11$, $p = .04$, $\eta^2 = .224$. Post-hoc, simple contrasts revealed that the ACI group was significantly less accurate than the ACIO group. There were no significant differences between the ACO and SCI group when compared to the ACIO group.

Aim 3: Predicting spoken target vocabulary words from pre-linguistic factors

To determine if the pre-linguistic factors of receptive language, vocal imitation, and frequency of unintelligible vocalizations at baseline predicted the number of spoken target vocabulary words at session 18 we again used a dummy-coded hierarchical regression. In block 1, we included the dummy coded groups previously mentioned above. In block 2, we added the pre-linguistic, baseline factors: receptive language, vocal imitation, and frequency of unintelligible vocalizations. This model was repeated with the session 24 number of spoken target vocabulary words.

At session 18, results of the first block revealed significant differences between ACO and ACIO groups when compared to the SCI group, $B = .36$, $t = 2.12$, $p = .04$ and $B = .66$, $t = 3.91$, p <.001 respectively. The nature of the slope suggests that both the ACO and ACIO group had significantly more spoken target vocabulary words than the SCI group. Results of the second block suggested that when controlling for pre-linguistic factors the ACO group and ACIO groups continued to be significant predictors of the number of target vocabulary words spoken when compared to the SCI group, $\beta = .38$ $t = 2.22$, $p = .032$ and $\beta = .65$, $t = 3.91$, $p < .001$ respectively. The only predictive factor that approached significance above and beyond the variance explained by intervention group was receptive language at baseline ($\beta = .25$, $t = 1.88$, $p = .067$). Overall, the variance explained in model 2 was not significantly better than in model 1, (model 1: $r^2 = .30$, $F\Delta(3,44) = 6.51$, $p = .001$ and model 2, $r^2 = .40$, $F\Delta(3,41) = 2.07$, $p = .12$) (see Table 6).

At session 24, results of the first block revealed significant differences between ACIO and SCI groups ($\beta = .63$, $t = 3.63$, $p = .001$). The nature of the slope suggests that the ACIO group had significantly more spoken target vocabulary words than the SCI group. Results of the second block suggested that when controlling for pre-linguistic factors the ACIO and ACO groups had significantly more words than the SCI group, $\beta = .37$ $t = 2.17$, $p = .036$ and $\beta = .62$, $t = 3.71$, $p = .001$ respectively. The receptive language at baseline factor also trended towards being a significant predictor ($\beta = .24$, $t = 1.83$, $p = .07$). Overall, the variance explained in number of spoken target vocabulary words at session 24 was significant in both models, $r^2 = .26$, $F\Delta(3,44) = 5.13$, $p = .004$ and $r^2 = .41$, $F\Delta(3,41) = 3.55$, $p = .02$ (see table 7).

To examine the receptive language as a possible moderator between group and number of different words, we first centered our predictors and computed interaction terms. There was no evidence of a moderator effect ($t = 1.24$, $p = .173$) therefore we did not probe the interaction further.

Table 5
Results of hierarchical regression group and pre-linguistic factors on number of different target vocabulary words at session 18

Model	Variable	B	SE(B)	β	t	p	r2	Sig Δ
1							.31	
	ACO*	3.83	1.80	.36	2.12	.04		
	ACI	.89	2.06	.07	.43	.67		
	ACIO*	7.43	1.90	.66	3.91	<.00		
2							.40	.12
	ACO*	4.04	1.82	.38	2.22	.03		
	ACI	.84	2.10	.07	.41	.68		
	ACIO*	7.40	1.90	.65	3.90	<.00		
	ReceptiveLanguage	.211	.112	.25	1.88	.067		
	Vocal Imitation	1.50	1.66	.12	.90	.37		
	UV at Baseline	-.002	.009	-.024	-.184	.86		

Note: *=significant predictor; ACO, ACI, ACIO are all dummy coded variables created with SCI as the comparison; Receptive Language= Raw receptive language score from MSEL, Mullen, 1995; UV at Baseline=Number of unintelligible utterances at baseline.

Table 6
Results of hierarchical regression group and pre-linguistic factors on number of different target vocabulary words at session 24

Model	Variable	B	SE(B)	β	t	p	r2	Sig Δ
1							.26	
	ACO	3.79	2.02	.33	1.88	.067		
	ACI	1.67	2.31	.12	.72	.47		
	ACIO*	7.71	2.12	.63	3.63	.001		
2							.41	.02
	ACO*	4.24	1.95	3.72	2.17	.036		
	ACI	2.07	2.20	.15	.94	.35		
	ACIO*	7.55	2.03	.62	3.71	.001		
	ReceptiveLanguage	.22	.12	.24	1.82	.075		
	Vocal Imitation	1.77	1.78	.13	1.00	.33		
	UV at Baseline	.01	.01	.16	1.20	.24		

Note: *=significant predictor; ACO, ACI, ACIO are all dummy coded variables created with SCI as the comparison; Receptive Language= Raw receptive language score from MSEL, Mullen, 1995; UV at Baseline=Number of unintelligible utterances at baseline.

When age was added to the model, the ACO and ACIO groups continued to be significant predictors of the number of different target vocabulary words at session 18 and session 24 (see tables 8 and 9). However, receptive language no longer trended towards significance at session 18 or at session 24, β = .15 *t* = 1.11, *p* = .27 and β = .51, *t* = .94, *p* = .35 respectively.

Table 7

Results of hierarchical regression group and pre-linguistic factors on number of different target vocabulary words at session 18 (with Age as factor)

Model	Variable	B	SE(B)	β	t	p	r2	Sig Δ
1							.43	
	Age	.31	.12	.37	2.74	.009		
	ACO*	3.75	1.61	.37	2.32	.03		
	ACI	1.80	1.88	.150	.96	.34		
	ACIO*	6.00	1.89	.51	3.18	.003		
2							.46	.55
	Age	.29	.11	.34	2.50	.02		
	ACO*	3.88	1.71	.39	2.27	.03		
	ACI	1.70	1.97	.14	.86	.39		
	ACIO*	6.18	1.95	.53	3.17	.003		
	ReceptiveLanguage	.13	.11	.15	1.11	.27		
	Vocal Imitation	.90	1.61	.07	.56	.58		
	UV at Baseline	-.001	.009	-.02	-.12	.91		

Note: *=significant predictor; ACO, ACI, ACIO are all dummy coded variables created with SCI as the comparison; Receptive Language= Raw receptive language score from MSEL, Mullen, 1995; UV at Baseline=Number of unintelligible utterances at baseline.

Table 8

Results of hierarchical regression group and pre-linguistic factors on number of different target vocabulary words at session 24 (with Age as factor)

Model	Variable	B	SE(B)	β	t	p	r2	Sig Δ
1							.29	
	Age	.23	.14	.25	1.65	.12		
	ACO*	3.73	1.93	.34	1.93	.06		
	ACI	2.32	2.24	.18	1.03	.31		
	ACIO*	6.41	2.26	.51	2.84	.007		
2							.41	.08
	Age	.17	.13	.19	1.32	.20		
	ACO*	4.26	1.93	.40	2.21	.03		
	ACI	2.79	2.22	.21	1.26	.22		
	ACIO*	6.42	2.20	.51	2.92	.006		
	ReceptiveLanguage	.12	.13	.12	.94	.35		
	Vocal Imitation	1.51	.181	.12	.83	.41		
	UV at Baseline	.02	.01	.22	1.56	.13		

Note: *=significant predictor; ACO, ACI, ACIO are all dummy coded variables created with SCI as the comparison; Receptive Language= Raw receptive language score from MSEL, Mullen, 1995; UV at Baseline=Number of unintelligible utterances at baseline.

DISCUSSION

In this study, we described the characteristics and phonemic properties of spoken target vocabulary and investigated the relationship between intervention group and spoken target vocabulary words at sessions 18 and 24 of a parent-coached, augmented language interventions. Additionally, we examined the contribution of the baseline factors receptive language, unintelligible utterances, and imitation on children's spoken vocabulary productions.

Research aim 1 investigated the characteristics of speech sounds for children with at least one spoken target vocabulary word at sessions 18 and 24. Overall, this study suggested that there were limited articulation errors made across all groups at the conclusion of intervention. Additionally, when we observed types of articulation errors, the majority of speech sound difficulties were age appropriate (e.g., gliding /r/, cluster reduction, etc.). These results confirm prior research that young children with developmental disorders beginning to speak produce developmentally appropriate speech-sound errors (Bauman-Waengler, 2013; Kumin et al., 1994; Shriberg, 1993; Van Bysterveldt, 2009). Additionally, these findings expand previous research that negates the potential negative effects of AAC intervention on articulation development in young children with developmental disorders (Miller et al., 2006; Romski et al., 2010; Romski & Sevcik, 1996).

Research aim 2 investigated the differences between groups for speech sound errors and across Shriberg's developmental classes of phonemes. No significant differences emerged between speech sound errors or across developmental sound classes at session 18, the end of the lab-based intervention. These findings support that children who participated in AAC interventions did not exhibit significantly more errors than children in the SCI group where speech was the focus of the intervention. Thus, intervention specifically targeting spoken language may not yield better accuracy of spoken target vocabulary words compared to AAC interventions. This adds to the literature that supports AAC as a means of early intervention, and dispute the idea that AAC may cause some detrimental effects to speech-sounds development.

At session 24, the conclusion of the home-based generalization phase, few significant differences were observed in types of errors generated. The ACIO group produced significantly more cluster reductions compared to the ACO, ACI, and SCI groups. All other speech sound errors (i.e., substitution, deletion, /r/ distortions, vowel distortions) were not significantly different between groups. This result supported the positive correlation observed between number of spoken target vocabulary words and number of errors. Together these findings suggest that as children in this study began to speak more fluently, they had more opportunities to produce errors. Producing more errors when beginning to speak is a common trait of emerging talkers and was not overly concerning to the researchers.

When considering the differences across developmental sound classes at session 24, only the Middle-8 phonemes revealed significant differences, such that children produced more erred sounds within the Middle-8 phonemes. This may be explained by the complex nature of middle 8 sounds that include backed-velar sounds /k/ and /g/, as well as sounds that required coordination of multiple articulators (e.g., labio-dental sounds such as /f/ and /v/). It may be important in future studies to control for phonemes present in target words across participants to more fully understand the impact of AAC intervention on the production of phonemes across all developmental sound classes.

In research aim 3, we investigated predictors of the number of spoken-target vocabulary words at session 18 and 24. Results demonstrated that participation in the ACO and ACIO groups significantly predicted the number of spoken target vocabulary words produced when compared to the SCI group above and beyond the contribution of age. The variance explained by intervention groups remained significant even after baseline predictors were added to the model. Although none of the baseline predictors were statistically significant, at session 24, the model that included the predictive factors explained significantly more variance in the number of spoken target words than the model without these factors. These findings support Romski et al. (2010) outcomes, which showed that participation in augmented intervention produced an increased probability of spoken target vocabulary. Unlike Warren et al. (1993) and Yoder and Layton (1988), these results did not support that vocal imitation or unintelligible vocalizations at baseline would predict spoken target-vocabulary outcomes. Baseline receptive language skills were also not significant in predicting the number of spoken target vocabulary words. This suggests that a prior level of language understanding may not be necessary to result in spoken language growth.

Clinical Implications

Outcomes of this study suggest that clinicians should use AAC with young children with severe communication disorder to support expressive language development without fear that it will impair articulation skills. The consistency of exposure to spoken target vocabulary words through an SGD may provide a model that is more easily imitated than the inflection and pronunciation variations observed during human discourse (Romski & Sevcik, 1996).

Additionally, hypothesized baseline factors (i.e., receptive language, unintelligible vocalizations, and imitation skills) were not significant predictors in the number of spoken target vocabulary words. This finding supports a growing body of evidence that rejects the myth that a certain level of prerequisite skill is required prior to intervening with AAC (Romski & Sevcik, 2005). The current study highlighted that the method of intervention is more important than the baseline skillset. Children in the ACO and ACIO intervention groups were more likely to generate spoken target vocabulary words regardless of their skills at baseline.

Providing multiple modalities for communication (AAC and speech) may decrease the pressure children feel to use any single modality (Lloyd & Kangas, 1994). Children in the augmented intervention groups produced more spoken target vocabulary words than children in the SCI group. If children with severe communication disorders receive speech therapy that is primarily focused on articulation skills they may become frustrated with communication and their speech difficulties. Providing AAC options allows these children to continue to develop expressive language abilities in parallel to articulation skills.

Limitations

It is important to acknowledge that there were several limitations to this study. Primarily, the goal of the two studies retrospectively analyzed for this project was not aimed at increasing the number of spoken-target vocabulary words or accuracy of speech sounds, rather to increase expressive language in general, across modalities. Therefore, we did not have any norm-referenced measures of articulation at pre-, during, or post- intervention stages. We also lacked a measure of dysarthria, which is a common speech disorder characteristic of children with cerebral palsy and other developmental disorders. Additionally, target vocabulary words were assigned to participants based on routines, individual preferences, and baseline vocabulary skills. Accordingly, there was no control for phoneme variability across participants. Also, due to the scope of this project, we only included reliably transcribed, “adult-like” spoken-target vocabulary in our analysis. This excluded phonetically consistent forms (PCFs) that may have highlighted more discrete articulation difficulties in children’s spoken language abilities. Thus error data represented in this study may be suppressed due to this omission. Although the sample size is larger than much of the research investigating the effects of AAC intervention, the sample may still have been too small to detect meaningful differences between groups especially in our regression model with six total predictors. Finally, the second study, Romski in preparation (2010), incorporated a waitlist condition. This might have contributed to the significant age difference between the intervention groups.

Future Directions

In the future, it may be important to more directly study the influence of AAC on spoken language development by using standardized articulation assessments throughout the intervention process. Additionally, examining participants' stimulability at pre-intervention may provide an interesting predictor variable for future studies. Future directions also may aim to include all spoken-communication during an AAC intervention to provide a more holistic picture of spoken-language development. Continued investigation of baseline factors may be important to understand if there are any circumstances in which we may be able to predict success with early AAC intervention. Finally, examining the frequency of exposure to target vocabulary words at home, in between sessions, may be beneficial to determine if the dosage of spoken input while not in the laboratory impacts spoken target vocabulary growth.

Together, these results dispute the myth that early AAC intervention has negative effects on speech sound production compared to spoken communication intervention. Combined with the significant group differences for number of spoken target vocabulary words, this evidence may inform both research and clinical practice to support the use of AAC for early, parent-coached interventions.

REFERENCES

Albert, P., Romski, M. A., & Sevcik, R. A., (2017). *Receptive language moderates the effects of AAC intervention on communication skills in children with developmental delays.* Poster presented at International Neuropsychology Society, New Orleans, Louisiana.

Arlt, P. B., & Goodban, M. T. (1976). A comparative study of articulation acquisition as based on a study of 240 normals, aged three to six. *Language, Speech, and Hearing Services in Schools*, *7*(3), 173-180.

Baillargeon, R., Spelke, E.S., & Wasserman, S. (1985). Object permanence in five-month old infants. *Cognition, 20, 191-208*.

Bandura, A., & Barab, P. G. (1971). Conditions governing non-reinforced imitation. *Developmental Psychology*, *5*(2), 244.

Barton, A., Sevcik, R. a, & Romski, M. A. (2006). Exploring visual-graphic symbol acquisition by pre-school age children with developmental and language delays. *Augmentative and Alternative Communication (Baltimore, Md. : 1985)*, *22*(1), 10–20.

Bauman-Waengler, J. (2013). *Articulatory and Phonological Impairments: Pearson New International Edition: A Clinical Focus*. Pearson Higher Ed.

Blischak, D. M. (1999). Increases in natural speech production following experience with synthetic speech. *Journal of Special Education Technology*, *14*(2), 44–53.

Blischak, D., Lombardino, L., & Dyson, A. (2003). Use of speech-generating devices: In support of natural speech. *Alternative and Augmentative Communication*, *19*(1), 29–35.

Berko-Gleason, J., & Bernstein-Ratner, N. (2008). *The Development of Language.* Boston, MA: Pearson Education Company.

Bauman-Leech, E.R. & Cress, C.J. (2011). Indirect facilitation of speech in a late talking child by prompted production of picture symbols or signs. *Augmentative and Alternative Communication, 27 (1),40–52.*

Branson, D., & Demchak, M. (2009). The use of augmentative and alternative communication methods with infants and toddlers with disabilities: A research review. *Augmentative and Alternative Communication*, *25*(4), 274–286. https://doi.org/10.3109/07434610903384529

Chen, H. P., & Irwin, O. C. (1946). Infant speech vowel and consonant types. *Journal of Speech Disorders*, *11*(1), 27-29.

Diehl, J. J., & Paul, R. (2012). Acoustic differences in the imitation of prosodic patterns in children with autism spectrum disorders. *Autism Spectrum Disorders*, *6*(1), 123–134.

Dodd, B. (1976). A comparison of the phonological systems of mental age matched, normal, severely subnormal and Down's syndrome children. *British Journal of Disorders of Communication, 11*(1), 27-42.

Fensen, L., Dale, P., Reznick, S., Thal, D., Bates, E., Hartung, J., Pethick, S., & Reilly, J. (1993). MacArthur communicative developmental inventories. *Baltimore: Paul H. Brookes*.

Fitch, W. T. (2005). The evolution of language: a comparative review. *Biology and philosophy*, *20*(2-3), 193-203.

Flahive, L. K., & Hodson, B. W. (2010). Speech sound disorders: An overview of acquisition, assessment, and treatment. *Language development: foundations, processes, and clinical applications*, 225-250.

Fudala, J. B. (2000). Arizona 3: Arizona Articulation Proficiency Scale, Third Revision. Western Psychological Services.

Gammon, C., & Dunn, C. (1985). *Normal and disordered phonology in children.* Baltimore, MD: University Park Press.

Goldman, R., & Fristoe, M. (2000). *Goldman-Fristoe Test of Articulation-2*. Circle Pines, MN: American Guidance Service.

Grunwell, P. (1981). *The nature of phonological disability in children*. Academic Press.

Hedrick, D. L., Prather, E. M., & Tobin, A. R. (1984). *Sequenced inventory of communication development*. Seattle: University of Washington Press.

Hustad, K. C., Allison, K., McFadd, E., & Riehle, K. (2014). Speech and language development in 2 year old children with cerebral palsy. *Developmental Neurorehabilitation*, *17*(3), 167-175.

Ingram, D. (1977). *Phonological disability in children* (Vol. 2). Elsevier Publishing Company.

Kent, R. D., & Vorperian, H. K. (2013). Speech impairment in down syndrome: A review. *Journal of Speech, Language and Hearing Research*, *56*, 178–210. https://doi.org/10.1044/1092-4388(2012/12-0148)

Kuhl, P. K., & Meltzoff, A. N. (1996). Developmental change. *Journal of Acoustical Society of America*, *100*, 2425–2438.

Kumin, L., Councill, C., & Goodman, M. (1994). A longitudinal study of the emergence of phonemes in children with Down syndrome. *Journal of Communication Disorders*, *27*(4), 293-303.

Leech, E. R. B., & Cress, C. J. (2011). Indirect facilitation of speech in a late talking child by prompted production of picture symbols or signs. *Augmentative and Alternative Communication*, *27*(1), 40-52.

Lloyd, L. L., & Kangas, K. (1994). Augmentative and alternative communication. In G. H. Shames, E. H. Wiig, & W. A. Secord (Eds.), *Human communication disorders,* (4th ed., pp. 606–657). New York: Merrill/Macmillan.

Mayer-Johnson. (1981). *Picture communication symbols*. Stillwater, MN: Author.

McNeil, D. (1970). *The acquisition of language: The study of developmental psycholinguistics*. New York, NY: Harper and Row.

Millar, D., Light, J., & Schlosser, R. (2006). The impact of augmentative and alternative communication intervention on the speech production of individuals with developmental disabilities: A research review. *Journal of Speech, Language, and Hearing Research, 49*(2), *248-264*.

Miller, J., & Chapman, R. (2000). *Systematic analysis of language transcripts* (SALT), Version 6.1. Madison, WI: University of Wisconsin, Language Analysis Lab.

Mullen, E. M. (1995). *Mullen scales of early learning*, 58-64. Circle Pines, MN: AGS.

Olive, M. L., de la Cruz, B., Davis, T. N., Chan, J. M., Lang, R. B., O'Reilly, M. F., & Dickson, S. M. (2007). The effects of enhanced milieu teaching and a voice output communication aid on the requesting of three children with autism. *Journal of Autism and Developmental Disorders*, *37*(8), 1505-1513.

Oller, D.K. (1980). The emergence of the sounds of speech in infancy. In G. Yeni-Komshian, J. Kavanagh, & C. Ferguson (Eds.), *Child phonology, Vol. 1: Production* (pp. 93–112). New York: Academic Press.

Parsons, C. L., & LaSorte, D. (1993). The effect of computers with synthesized speech and no speech on the spontaneous communication of children with autism. *Australian Journal of Human Communication Disorders*, *21*(1), 12-31.

Paul, R., & Norbury, C. F. (2012). Language disorders from infancy through adolescence: listening, speaking. *Reading, Writing, and Communicating*, *4*.

Pena-Brooks, A. & Hedge, M. N. (2000). *Assessment and treatment of particulation and phonological disorders in children.* Austin, TX: PRO-ED.

Piaget, J. (1964). Part I: Cognitive development in children: Piaget development and learning. *Journal of research in science teaching, 2*(3), 176-186.

Poole, I. (1934). Genetic development of articulation of consonant sounds in speech. *The Elementary English Review*, *11*(6), 159-161.

Prather, E. M., Hedrick, D. L., & Kern, C. A. (1975). Articulation development in children aged two to four years. *Journal of Speech and Hearing Disorders*, *40(*2), 179-191.

Preisser, D. A., Hodson, B.W., & Paden, E.P. (1988) Developmental phonology: 18-29 months. *Journal of Speech and Hearing Disorders, 53, 125-130.*

Preston, J. L., Irwin, J. R., & Turcios, J. (2015). Perception of speech sounds in school-aged children with speech sound disorders. *Seminars in Speech and Language*, *36*(4), 224–33.

Rees, N. S. (1975). Imitation and language development: issues and clinical implications. *The Journal of Speech and Hearing Disorders*, *40*(3), 339–350.

Romski, M. A., & Sevcik, R. A. (1996). *Breaking the speech barrier: Language development through augmented means.* Baltimore, MD: Brooks.

Romski, M., & Sevcik, R. A. (2005). Augmentative communication and early intervention myths and realities. *Infants & Young Children, 18*(3), 174–185.

Romski, M. A., Sevcik, R. A., Adamson, L. B., Cheslock, M., Smith, A., Barker, R., & Bakeman, R. (2010). Randomized comparison of augmented and nonaugmented language interventions for toddlers with developmental delays and their parents. *Journal of Speech, Language, and Hearing Research, 53, 350-364.*

Romski, M. A., Sevcik, R. A., Cheslock, M., & Barton-Hulsey, A. (2016). The system for augmenting language: AAC and emerging language intervention. In R. McCauley, M. Fey, & R. Gillam (Eds.) *Treatment of language disorders in children: Conventional and controversial interventions.* (2nd ed., pp. 155-186). Baltimore, MD: Paul H. Brookes Publishing.

Romski, M.A., Sevcik, R.A., Adamson, L.B., Barton-Hulsey, A, Smith, A., Barker, R. M., Whitmore, A., & Bakeman, R (in preparation). Assessing the effects of parent-coached early augmented language intervention for toddlers with developmental disabilities.

Romski, M. A., Sevcik, R. A., & Pate, J. L. (1988). Establishment of symbolic communication in persons with severe retardation. *Journal of Speech and Hearing Disorders, 53*(1), 94-107.

Ruston, H. P., & Schwanenflugel, P. J. (2010). Effects of a conversation intervention on the expressive vocabulary development of prekindergarten children. *Language, Speech, and Hearing Services in Schools*, *41*(3), 303–313.

Sander, E. (1972). When are speech sounds learned? *Journal of Speech and Hearing Disorders, 57*, 55-63.

Schlosser, R. W., Sigafoos, J., Luiselli, J. K., Angermeier, K., Harasymowyz, U., Schooley, K., & Belfiore, P. J. (2007). Effects of synthetic speech output on requesting and natural speech production in children with autism: A preliminary study. *Research in Autism Spectrum Disorders*, *1*(2), 139-163.

Schlosser, R., & Blichak, D. (2001). Is there a role for speech output in interventions for persons with autism? A review. *Focus on autism and other developmental disabilities, 16*(3), *170-176.*

Schlosser, R. W., & Wendt, O. (2008). Effects of augmentative and alternative communication intervention on speech production in children with autism: A systematic review. *American Journal of Speech-Language Pathology*, *17*(3), 212-230.

Secord, W., & Donohue, J. S. (2014). *CAAP-2: Clinical assessment of articulation and phonology-2*. Super Duper Publications.

Shriberg, L. D. (1993). Four new speech and prosody-voice measures for genetics research and other studies in developmental phonological disorders. *Journal of Speech and Hearing Research, 36, 105-140.*

Shriberg, L. D., & Austin, D. (1997). The percentage of consonants correct (pcc) metric: Extensions and reliability data. *Journal of Speech, Language & Hearing Research, 40*(4), 708.

Shriberg, L. D., & Kwiatkowski, J. (1982). Phonological disorders III: A procedure for assessing severity of involvement. *Journal of speech and Hearing Disorders*, *47*(3), 256-270.

Slobin, D. I., & Welsh, C. A. (1967). Elicited imitation as a research tool in developmental psycholinguistics.

Smit, A., Hand, L., Freilinger, J., Bernthal, J., & Bird, A. (1990). The Iowa articulation norms project and its Nebraska replication. *Journal of Speech and Hearing Disorders, 55*, 779-798.

Smith, M., & Grove, N. (2003). Asymmetry in input and output for individuals who use AAC. In Light, D. Beukelman, & J. Reichle (Eds.), *Communicative competence for individuals who use augmentative and alternative communication: From research to effective practice* (pp. 163-195). Baltimore, MD: Brookes.

Smith, B. L., & Stoel-Gammon, C. (1983). A longitudinal study of the development of stop consonant production in normal and Down syndrome children. *Journal of Speech and Hearing Disorders*, *48*(2), 114-118.

Sommers, R. K., Reinhart, R. W., & Sistrunk, D. A. (1988). Traditional articulation measures of Down syndrome speakers, ages 13-22. *Journal of Childhood Communication Disorders*, *12*(1), 93-108.

Sparrow, S. S., Cicchetti, D. V., & Balla, D. A. (2005). Vineland adaptive behavior scales: Survey interview form/caregiver rating form. *Livonia, MN: Pearson Assessments*.

Stoel-Gammon, C. (2001). Down syndrome phonology: developmental patterns and intervention strategies. *Down's Syndrome, Research and Practice*, *7*(3), 93–100.

Templin, M., & Steer, M. D. (1939). Studies of growth of speech of pre-school children. *Journal of Speech Disorders*, *4*(1), 71-77.

Templin, M. C. (1957). Certain language skills in children, their development and interrelationships. *Institute of Child Welfare, Monograph Series, No. 26.* Minneapolis, MN: University of Minnesota Press.

Van Bysterveldt, A. K. (2009). Speech, phonological awareness and literacy in New Zealand children with Down syndrome.

Warren, S. F., Yoder, P. J., Gazdag, G. E., Kim, K., & Jones, H. A. (1993). Facilitating prelinguistic communication skills in young children with developmental delay. *Journal of Speech and Hearing Research*, 36, 83–97.

Widaman, K. (2006). Missing data: What to do with or without them. *Monographs of the Society for Research in Child Development*, *71*(3), 42–64.

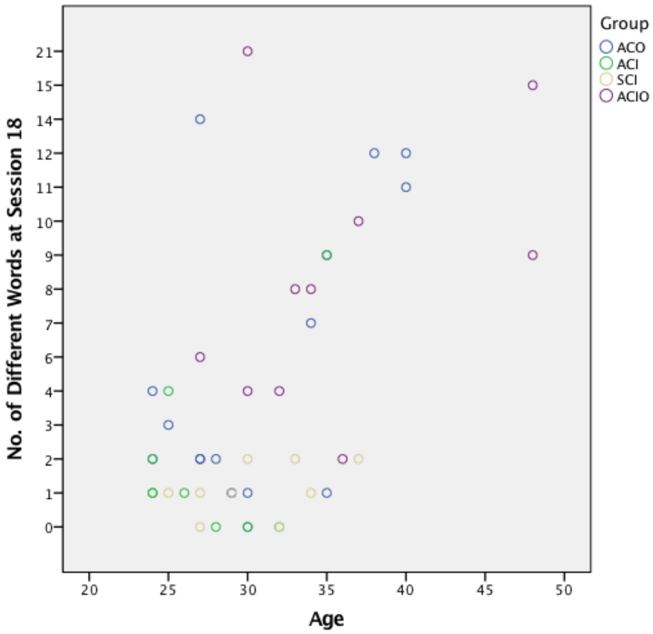
Wellman, B., Case, I., Menegert, I., & Bradbury, D. (1931). Speech sounds of young children. *University of Iowa Studies on Child Welfare, 5, 1-82.*

Yoder, P. J., & Layton, T. L. (1988). Speech following sign language training in autistic children with minimal verbal language. *Journal of Autism and Developmental Disorders*, *18*(2), 217-229.

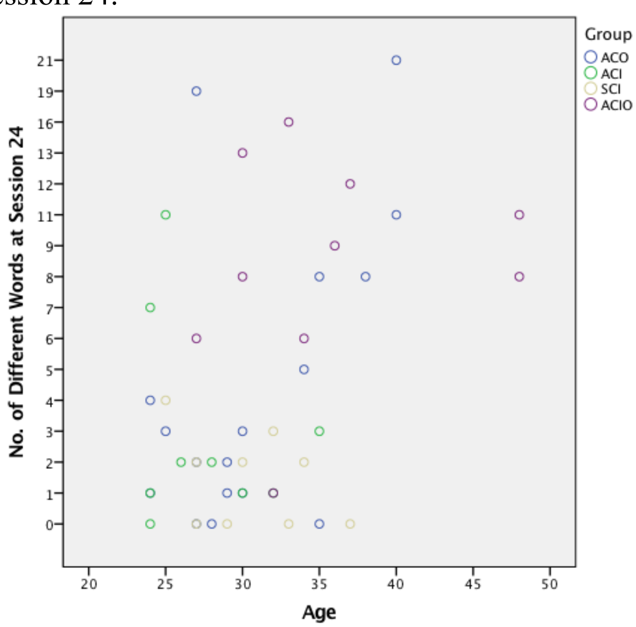
APPENDICES

Appendix A

Session 18:



Session 24:



:

Appendix B:

Session 18: Early 8

Summary Data

	N	Mean	Std. Deviation	Std. Error Mean
Early 8_18_mean	38.000	.849	.284	.046
Early_8_18	37.000	.872	.250	.041

Independent Samples Test

	Mean Difference	Std. Error Difference	t	df	Sig. (2-tailed)
Equal variances assumed	-.023	.062	-.372	73.000	.711
Equal variances not assumed	-.023	.062	-.372	72.299	.711

Hartley test for equal variance: F = 1.287, Sig. = 0.2226

Session 18: Middle 8

Summary Data

	N	Mean	Std. Deviation	Std. Error Mean
Mid 8_18_mean	38.000	.890	.234	.038
Mid_8_18	22.000	.859	.260	.056

Independent Samples Test

	Mean Difference	Std. Error Difference	t	df	Sig. (2-tailed)
Equal variances assumed	.030	.065	.465	58.000	.644
Equal variances not assumed	.030	.067	.452	40.281	.654

Hartley test for equal variance: F = 1.235, Sig. = 0.2774

Session 18: Late 8

Summary Data

	N	Mean	Std. Deviation	Std. Error Mean
Late_8_18_mean	38.000	.782	.287	.047
Late_8_18	32.000	.773	.266	.047

Independent Samples Test

	Mean Difference	Std. Error Difference	t	df	Sig. (2-tailed)
Equal variances assumed	.010	.067	.144	68.000	.886
Equal variances not assumed	.010	.066	.145	67.344	.885

Hartley test for equal variance: F = 1.164, Sig. = 0.3324

Session 18: Total

Summary Data

	N	Mean	Std. Deviation	Std. Error Mean
Total_18_mean	38.000	.839	.233	.038
Total_8_18	32.000	.839	.233	.041

Independent Samples Test

	Mean Difference	Std. Error Difference	t	df	Sig. (2-tailed)
Equal variances assumed	.000	.056	.000	68.000	1.000
Equal variances not assumed	.000	.056	.000	65.988	1.000

Hartley test for equal variance: F = 1.000, Sig. = 0.5039

Session 24: Early 8

Summary Data

	N	Mean	Std. Deviation	Std. Error Mean
Early 8_24_mean	38.000	.849	.284	.046
Early_8_24	38.000	.888	.203	.033

Independent Samples Test

	Mean Difference	Std. Error Difference	t	df	Sig. (2-tailed)
Equal variances assumed	-.039	.057	-.689	74.000	.493
Equal variances not assumed	-.039	.057	-.689	66.928	.493

Hartley test for equal variance: F = 1.963, Sig. = 0.0203

Session 24: Middle 8

Summary Data

	N	Mean	Std. Deviation	Std. Error Mean
Mid 8_24_mean	38.000	.822	.208	.034
Mid_8_24	25.000	.824	.229	.046

Independent Samples Test

	Mean Difference	Std. Error Difference	t	df	Sig. (2-tailed)
Equal variances assumed	-.001	.056	-.023	61.000	.981
Equal variances not assumed	-.001	.057	-.023	47.981	.982

Hartley test for equal variance: F = 1.211, Sig. = 0.2915

Session 24: Late 8

Summary Data

	N	Mean	Std. Deviation	Std. Error Mean
Late_8_24_mean	38.000	.690	.310	.050
Late_8_24	35.000	.655	.308	.052

Independent Samples Test

	Mean Difference	Std. Error Difference	t	df	Sig. (2-tailed)
Equal variances assumed	.035	.072	.488	71.000	.627
Equal variances not assumed	.035	.072	.489	70.582	.627

Hartley test for equal variance: F = 1.013, Sig. = 0.4863

Session 24: Total

Summary Data

	N	Mean	Std. Deviation	Std. Error Mean
Total _24_mean	38.000	.810	.149	.024
Total_8_18	39.000	.810	.149	.024

Independent Samples Test

	Mean Difference	Std. Error Difference	t	df	Sig. (2-tailed)
Equal variances assumed	.000	.034	.000	75.000	1.000
Equal variances not assumed	.000	.034	.000	74.948	1.000

Hartley test for equal variance: F = 1.000, Sig. = 0.4994

Appendix C

We also compared group differences in accuracy of spoken target vocabulary words by regressing total PCC and PPC on dummy coded groups in separate analyses. This allowed us to compare each of the augmented groups to a comparison group, spoken communication input. For PCC measures at session 18 and 24, results of the dummy coded regression analysis revealed that the models did not fit because these group differences did not explain enough variance in the dependent variable, F=.33, p=.81 and F=1.66, p=.19 respectively. Another possible explanation of this finding is that the restricted range observed in the PCC data was not sensitive to detecting differences between the groups. Similarly, intervention groups at session 18 did not explain significant variance in PPC measures, F=.74, p=.54. However, at session 24, the ACI and ACIO group when compared to the SCI group were significant predictors of PPC, B = -.58, t = -2.78, p=.009 and B = -.53, t=-2.24 p=.032). The nature of these slopes suggests that the SCI group produced significantly more accurate phonemes than the ACI and ACIO groups. This supports the descriptive results reported above.

Appendix D

Correlation Matrix

Correlation Matrix for Session 18

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. No. Different words	-												
2. Early 8 PCC	.1	-											
3. Middle 8 PCC	.08	.66**	-										
4. Late 8 PCC	-.36*	.45**	.65**	-									
5. Total 8 PCC	-.07	.75**	.92**	.81**	-								
6. No. Phonemes in gloss	.99**	.12	.10	-.36*	-.02	-							
7. No. Phonemes w/o error	.94**	.15	.13	-.23	.06	.95**	-						
8. FCD	.45**	-.25	-.42**	-.61**	-.52**	.43**	.24	-					
9. Substitution	.48**	-.07	-.34*	-.54**	-.37*	.49**	.41*	.67**	-				
10. Deletion	.38*	-.26	.02	-.12	-.16	.40*	.41*	.30	.24	-			
11. Cluster Reduction	.66**	.02	-.07	-.51**	-.20	.69**	.65**	.25	.27	.25	-		
12. Vocalic /r/	.63**	.08	.17	-.22	.03	.62**	.52**	.43**	.20	.40*	.44**	-	
13. Vowel error	.16	.01	-.11	-.36*	-.19	.13	-.07	.42**	.38*	.02	.04	.15	-
14. Other	.07	.03	.11	-.02	.09	.10	.09	-.03	.06	.09	-.17	.05	-.07

Note: * *p*<.05, ***p*<.01

Correlation Matrix for Session 24

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. No. Different words	-												
2. Early 8 PCC	-.04	-											
3. Middle 8 PCC	-.08	.10	-										
4. Late 8 PCC	.01	-.23	-.08	-									
5. Total 8 PCC	.001	.53**	.53**	.58**	-								
6. No. Phonemes in gloss	.98**	-.02	-.11	-.05	.03	-							
7. No. Phonemes w/o error	.96**	.02	-.05	-.03	.07	.99**	-						
8. FCD	.43**	-.28	-.42*	-.02	-.21	.41*	.31	-					
9. Substitution	.77**	-.07	-.19	-.13	-.12	.79**	.74**	.39*	-				
10. Deletion	.35*	-.33*	.05	-.03	-.14	.32*	.28	.59**	.20	-			
11. Cluster Reduction	.70**	.01	-.27	-.26	-.14	.76**	.75**	.26	.53**	.27	-		
12. Vocalic /r/	.45**	-.06	-.15	-.20	-.11	.46**	.41**	.13	.64**	-.05	.40*	-	
13. Vowel error	.37	.01	-.06	-.21	.06	.31	.23	.34*	.28	.34*	.18	.22	-
14. Other	.60	-.09	-.03	-.1	-.06	.57**	.48**	.50**	.55**	.30	.39*	.18	.67**

Note: * *p*<.05, ***p*<.01